NUCLEAR
ASSURANCE
CORPORATION

URANIUM IN SITU LEACH MINING STUDY

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LEACH MINING STUDY

NUCLEAR ASSURANCE CORPORATION

Corporate Office:
24 Executive Park West
Atlanta, Georgia 30329
Telephone: (404) 325-4200
Telex: 549567 and 542703

European Office:
Weinbergstrasse 9
8001 Zurich, Switzerland
Telephone: (01) 47 08 44
Telex: 57275

Uranium Operations Office:
715 Horizon Drive
Grand Junction, Colorado 81501
Telephone: (303) 245-4320
TWX: 9109296334

Nuclear Assurance Corporation's report entitled "URANIUM IN SITU LEACH MINING STUDY" presents a comprehensive overview of in situ leach technology, economics, and production in the United States. This report is organized into two parts.

Part One discusses in situ leach project feasibility and economics, project scheduling and environmental/regulatory requirements and procedures. A cost model for preliminary feasibility analysis of in situ leach projects comprises a major portion of Part One. The model is designed to accept site specific cost information; suggested generic cost data are provided for input into the model where site specific data are not available. Use of the model is fully documented and an example calculation using the model is included. The model is intended for use by technical managers and geologists, both to complete <u>preliminary</u> project feasibility studies and to better acquaint themselves with in situ leach economics and project timing and scheduling. A list of parameters to be considered in the technical evaluation of in situ leach feasibility is included. Part One also provides a comprehensive summary of environmental permits and licenses required for an in situ leach project plus estimated costs for permit preparation and typical review and approval periods.

Part Two of the report includes summary information on all operating or planned in situ leach projects in the U. S. The following technical information is presented on most of the in situ leach projects:

1. Ore grade, thickness and depth
2. Deposit geology
3. Estimated reserves
4. Plant size and production capacity

5. Leach chemistry and extractive metallurgy
6. Well field design and engineering
7. Aquifer restoration
8. Project status.

Part Two provides a thorough review of the in situ leach industry and the state of the art in ISL technology.

Exhibit I is a summary of the report format and an example of the type of data provided on the ISL projects.

As a supplement to the in situ leach report, NAC has developed a computer program for the ISL generic cost model. The computer program parallels the generic model as described in the report and requires the same input data as the hand-calculation model. The program output results in a year-by-year cash flow for a project and summary financial and economic statistics. The program allows for a rapid assessment of project sensitivity to different input parameters. To facilitate sensitivity analysis, the program is designed to store input data and modify one or more parameters for additional runs.

The in situ leach cost model computer program is interactive and user oriented. The program is written in UNIVAC ASCII Fortran which conforms to industry-wide Fortran 77 standards. The cost of running the program on NAC's in-house computer is less than $1.00 per run. The in situ leach cost model computer program includes:

1. A magnetic tape with program listing and programmer documentation, and
2. User documentation.

EXHIBIT I

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URANIUM IN SITU MINING STUDY
ABSTRACT

This report is designed to provide the basic information needed to perform initial feasibility studies on uranium properties considering the in situ leach method of extraction. The report is divided into two basic sections: Part One includes sections on economics, environmental regulations, in situ leach project management and a technical parameters checklist. Part Two is a description of current and past uranium in situ leach operations, both commercial and pilot-scale. These sections when taken together provide the data needed to complete technical and economic feasibility studies of potential in situ leach projects.

The report can also be considered as a reference source for information on in situ leaching. An extensive bibliography is included which lists references used herein and on the general subject of uranium in situ leaching, plus information on unconventional sources of uranium, e.g. hydraulic mining, heap leaching, leaching old mines, "unconventional" in situ leaching, etc. Finally, a glossary of terms has been added, listing some of the more common terms used in uranium in situ leaching.

INTRODUCTION

The objective of this report is to provide the information necessary to perform initial feasibility studies on uranium properties considering the in situ leach method of extraction (ISL). The objective was divided into two main work tasks: (1) obtain as much information (the who, where, why, how) as possible about current uranium in situ operations, and (2) design a feasibility study checklist that would provide the information with which to perform in situ feasibility studies.

Part One of the report includes separate sections on economics, environmental regulations, ISL project management and a technical parameter checklist. On the one hand, each of these topics is independent of the other topics and thus the separation into individual sections. However, from a total ISL project perspective, all the topics are interrelated insofar as each is an integral part of an overall project analysis or evaluation. Taken as a whole, Part One is a presentation of the information that is needed and/or must be considered in a technical and economic feasibility study of an ISL project. The overall objective in preparing Part One was to provide as complete data as possible to serve as the basis for evaluating the potential for ISL extraction on existing properties or future acquisitions.

"Order of magnitude" cost data are provided in Part One to serve as guidelines in preparing preliminary feasibility studies. The cost data are generic, and feasibility studies prepared from these data would be preliminary in nature and would not replace traditional, comprehensive studies that must be performed prior to final project decision making. Instead, the data are intended to (1) serve as an initial evaluation tool, (2) highlight or "flag" those parameters one must consider in the evaluation process and (3) elicit the "new thought" processes that will be required for the continued evaluation process during in situ project development.

The second part of the report contains an overview of past and current ISL mining operations in the United States. A total of 25 different companies and 47 operations (pilot-scale and commercial-past and current) are reviewed. The geographical distribution of these operations is as follows: Wyoming - 19, Texas - 19, New Mexico - 5, Colorado - 2, Montana - 1, and Utah - 1.

Each operation is individually discussed in Part Two. However, summary information for these 47 operations is presented in the following Table A. The basic format for these reviews includes the following sections: Location, Background Information, Project Description, Current Status, and Project Summary. Figures are included of plant layout, well field design, well completion techniques, etc. for the various operations. Part Two is intended to provide an overview of the current status of the emerging uranium in situ leach industry.

The report includes an extensive bibliography that can be considered as a reference source for information on uranium in situ mining. There are also references included on the following subjects: heap leaching, hydraulic mining, bacterial leaching, leach of old mines, natural leaching, in situ leaching above the water table, by-product uranium extraction (copper and phosphate) and other unconventional methods of uranium production. Finally, a glossary of terms has been added listing some of the more common terms used in uranium in situ leach mining.

PART 2
INDIVIDUAL URANIUM
IN SITU LEACH OPERATIONS

2.11 URANIUM RESOURCES INCORPORATED BENAVIDES PROJECT

LOCATION

Uranium Resources, Inc. is operating the Benavides Project located approximately 3.5 miles east of Bruni, Texas along the Arroyo de los Angeles in Sections 21 and 22 of the Santa Maria de los Angeles de Arriba, Mariano Arrispe Grant, in southwest Duval County, Texas.

BACKGROUND INFORMATION

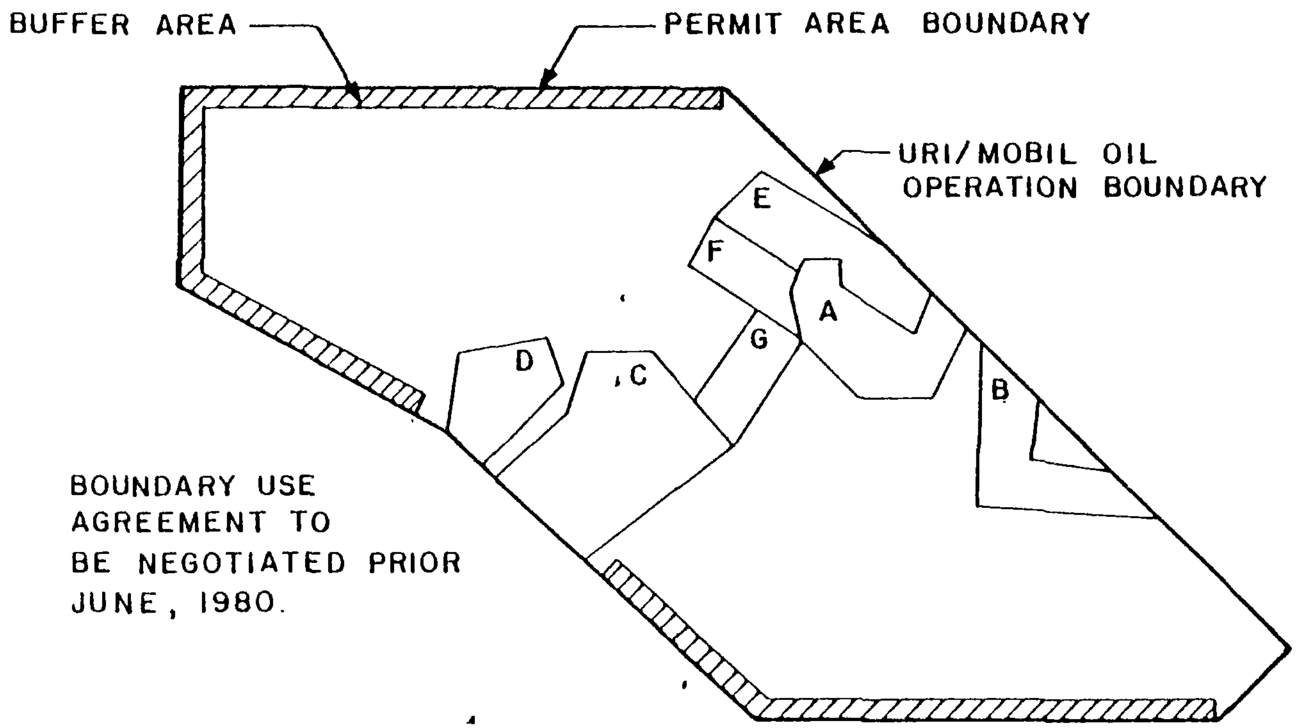
Uranium Resources, Inc. (URI) is a Richardson, Texas based uranium producer/operator. URI also operates the Longoria Project located approximately 3.5 miles south-southeast of the Benavides Project. The Benavides Project is also owned by Conoco (25 percent) and FRAMCO, French American Metals Corporation (25 percent). The application for an in situ mining license was submitted to the Texas Department of Water Resources in July 1979 and the license was issued February 4, 1980. The plant was started in February, 1980.

PROJECT DESCRIPTION

Ore Body

The Benavides ore body area is divided into seven (7) defined production areas totalling 47.63 acres. The production zone is in the Soledad Member of the Miocene Catahoula Formation and consists of three (3) distinct sands at depths of from 200 to 330 feet. The production areas are illustrated in Figure 2.34.

2.11.2



MINE AREA	ACREAGE
A	8.3
B	6.11
C	14 27
D	5.51
E	7.53
F	3.66
G	2.25
TOTAL	47.63

N

AVERAGE DEPTH – PRODUCTION ZONE : 230'
AVERAGE ELEVATION – PRODUCTION ZONE : 460' msl

URANIUM RESOURCES INC.

BENAVIDES PROJECT
MINE PLAN
CONFIGURATION OF MINE AREAS

SCALE 1" = 1000'

All of the 18 wells sampled within the permit area exceeded USPHS drinking water standards for sodium, chloride and total dissolved solids. The percent of excess varied from two (2) percent to 278 percent. The average percent of excess above USPHS standards amounted to 96 percent for sodium, 164 percent for chloride, and 44 percent for total dissolved solids.

Livestock watering is the only existing ground water use for which permit area subsurface waters are suited.

Well Completion

All production and monitor wells are completed in the same manner. Total drilling depth calculations are made by use of existing exploration geophysical logs. All production wells are drilled to a depth of at least five (5) feet below the mineralized zone in the host unit. All production zone monitor wells are drilled to a depth of at least five (5) feet below the base of the mineralized production zone. Non-production zone monitor wells are drilled to a total depth which coincides with the top of the clay seam separating the production zone from the overlying non-production zone.

Once the well is drilled to a total depth, the bore hole is conditioned with polymer drilling mud. Thereafter, PVC well screen is made up for the desired completion interval. Monitor wells and production wells have an average completion interval of 15 feet. Immediately above the screen is the cementing joint and cement basket.

The remaining tubular goods consist of fiberglass well casing which is made up with strap wrench tongs as the casing is run into the hole. Fiberglass well casing utilized on the Benavides Project meets, or exceeds the following specifications:

Casing Size:	4" nominal
Inside Diameter:	4.33"

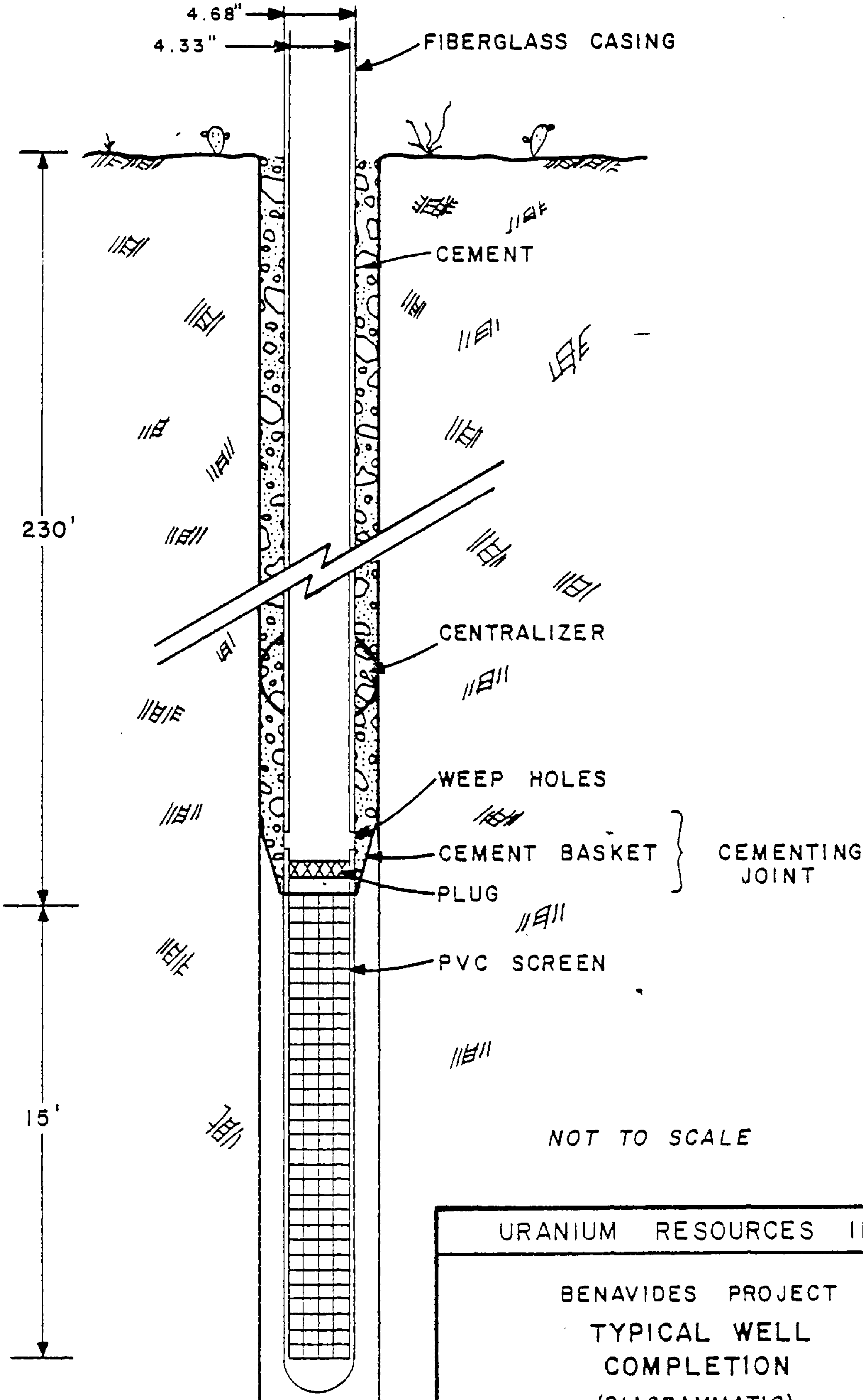
Outside Diameter:	4.65"
Wall Thickness:	0.175"
Weight Per Foot:	3.1 lb.
Length of Joint:	22.25'
O.D. at Upset:	5.5"
Thread:	Fiberglass W/"O" Ring
Operating Pressure:	1,000 psi
Ultimate Collapse:	1,100 psi
Operating Temperature:	150 degrees F. Max.
Operating Tensile Load Across Joint	15,000 lbs.

The second, third, and fourth joint of casing above the cementing joint have centralizers attached as they are placed in the hole. Depth for landing the screen is determined by the base of mineralization in the production interval. For a diagrammatic representation of well design and completion refer to Figure 2.35.

After the casing is landed the drilling rig is moved off location and a cementing unit is moved on. A cementing nipple is attached to the casing collar and circulation is broken with clear water; and clear water is circulated for approximately ten (10) minutes. At this time, a cement slurry is pumped into the well casing. All cement slurries utilized on the Benavides Project are made up to the following specifications:

Cement Type:	Class "A"
Additives:	4% Bentonite Gel
Volume:	1.1 to 1.2 x Casing/hole annulus volume
Slurry Weight:	14.1 lbs/gal.
Cement Water Ratio:	7.8 gal/sk cement

After the prescribed volume of cement slurry is pumped into the casing the cement nipple is removed, a cement wiper plug is placed in the casing, and the cementing nipple is



URANIUM RESOURCES INC.

BENAVIDES PROJECT

TYPICAL WELL COMPLETION

(DIAGRAMMATIC)

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reattached. The wiper plug is then pumped down to the bottom of the casing with clear water which displaces the cement out of the casing through the weep holes and into the casing bore hole annulus. Once the wiper plug reaches bottom, the casing interior is pressured to 50 psi and the well is shut in until the cement has cured.

Thereafter, the wiper plug and Plaster of Paris plug are drilled out. The well is then produced by jetting until produced waters are free of drilling sediments and have obtained attenuated pH, temperature, and conductivity levels.

Extraction Plant

The Benavides extraction plant has a nominal flow capacity of 1600 gallons per minute and an annual nominal production rate of 250,000 lb U_3O_8. Four (4) upflow fluidized bed, single stage ion exchange columns are used for uranium loading. Two (2) separate elution vessels are used. Precipitation is carried out in five (5) agitated tanks. A filter press is used for yellowcake dewatering prior to slurry shipment.

Process Description

Uranium minerals are leached in situ from the host sand by a two (2) step process of oxidation and solubilization. A lixiviant solution composed of a bicarbonate anion complexing agent and oxygen (gaseous and as peroxide) is introduced to the host sand where the following reactions occur:

$$2UO_2 + O_2 = 2UO_3 \qquad (1$$

$$2UO_3 + Na_2CO_3 + 2NaHCO_3 = Na_4UO_2(\ O_3)_3 + H_2O \qquad (2$$

The final uranyl tricarbonate complex is soluble and is extracted from the subsurface by pumping. Produced fluids pass into one of two pregnant lixiviant surge tanks. From this point the pregnant lixiviant passes in series through four (4) upflow ion exchange columns in which the uranyl tricarbonate anion complex is stripped from the solution. This is accomplished by ion exchange of the uranium complex onto positively charged resins coupled with simultaneous displacement of chloride anion through the following reaction:

$$4RDl + Na_4UO_2(CO_3)_3 = R_4UO_2(CO_3)_3 + 4NaCl \qquad (3$$

The now-barren leach solution passes to the barren lixiviant surge tank. From this point the barren solution is pumped across three (3) sand filters for removal of particulates and any precipitates which may have evolved in the ion exchange process. Thereafter, the solution is re-fortified with lixiviant chemicals, Na_2CO_3 and oxidant, and reinjected into the formation for a new leach cycle.

Once all ion exchange sites are filled on the resin in a particular ion exchange column, the column is taken off stream and resin therein is transferred to one of two elution columns. Previously eluted resin from the remaining elution column is transferred to the empty ion exchange column.

"Loaded" resin is stripped of uranium through a two step elution process based on the following reaction:

$$R_4UO_2(CO_3)_3 + 4NaCl = 4RCl + Na_4UO_2(CO_3)_3 \qquad (4$$

The first elution pass is made with recycle eluant. The uranium fortified solution passes to pregnant eluant storage. The second elution pass is made with barren eluant. The resulting slightly uranium rich solution passes to the recycle eluant storage. At this point the resin is stripped of uranium and is held for transfer.

When a sufficient volume of pregnant eluant is held, eluant is transferred to the first precipitation tank, and is acidified with hydrochloric acid until the pH is lowered to two (2). The acidified eluant is then transferred to precipitation tank number two where it is agitated in order to vent off CO_2. The acid digest is completed in precipitation tank number three where hydrogen peroxide is added in order to achieve maximum uranium oxidation state. Uranium is precipitated in tank number four where sodium hydroxide is added until hydrolization commences. The precipitate is transferred to tank number five for completion of precipitation.

Thereafter the uranium slurry is transferred to the yellowcake slurry tank. The yellowcake is then batch washed in the filter press and subsequently pumped into the yellowcake slurry trailer to await shipment.

Mine Plan

The estimated mine life of the Benavides Project is 4.75 years for the mine areas shown in Figure 2.34. Drilling or variability in operations may affect this estimate. A staggered line drive well field pattern with variable spacing is being used.

When wells cease to be productive they will be shut in and partial restoration will begin, through displacement of mine waters by unaffected waters which are being pulled in in response to the bleed stream. When an entire mine area has ceased to be productive it will enter a full restoration mode and its production will be replaced by a new mine area(s).

Restoration Plan

Based on restoration tests conducted by Mobil Oil Corporation on non-ammonia leach operations in the Benavides Project area, URI estimates that full restoration can be accomplished by fluid displacement of mine waters with unaffected water from the surrounding production vicinity; i.e., ground water sweeping. The total production volume required to achieve restoration is calculated to be slightly less than five (5) times the pore volume of the affected production interval.

Fluids produced by this restoration technique will be treated by reverse osmosis (R.O.). The reject stream will be disposed by subsurface injection. The purified stream will be spray irrigated on the permit area as part of the surface restoration program. If for any reason, the purified stream does not meet acceptable standards for surface irrigation R.O., treatment will cease and all fluids will be disposed by subsurface injection.

Restoration rate will be monitored through analysis of waters produced from the formation. A sample will be taken weekly from the composite production line and analyzed for conductivity, sulfate, chloride, and uranium.

When this data indicates that restoration is at or near completion, URI will sample each original baseline well and analyze for the parameters listed in the table below:

RESTORATION PARAMETERS

Ca	CO_3	NO_3N	Ec@ 25 c
Mg	HCO_3	FL	Ec (dilute)
Na	SO_4	S_iO_2	Alk. as $CaCO_3$
K	CI	TDS @180 c	pH

If the well field mean value for each chemical parameter is equal to or below the original mean plus one standard deviation, or the accepted drinking water limit, restoration is considered to be completed.

At such time, the state will be notified and a time selected for split sample collection for analytical verification of restoration achievement. Three (3) sample sets will be taken at one month intervals from the original baseline wells. Providing no significant changes between the first two (2) analyses, the third sample set will be analyzed for the minor and trace constituents originally reported. If the major and minor constituents reported for all three (3) sample sets are within the restoration limit, URI considers that restoration is complete and is under no further obligation for continued subsurface restoration.

After aquifer restoration has been accomplished all lateral and master manifold pipelines will be removed from the property. Lines that are not reusable will be decontaminated and disposed of by salvage sale or destruction. Salvageable lines will be held by URI for use in other in situ leach activities. All well head equipment, i.e. valves, meters, control panels, etc. will be salvaged or destroyed in a like manner.

All production, injection, and monitor wells will be plugged and abandoned in the following manner. First, a cement plug will be placed in the well bore from total depth to a level at least 50 feet above the completion interval. Thereafter, the casing will be filled with drilling mud from the top of the bottom plug to a level 15 feet below ground. A second cement plug will be set from 15 feet to 3 feet below ground surface. The casing will then be cut at the top of the cement and the upper three (3) feet will be pulled. The resulting hole will be backfilled with native soil. Two (2) exceptions could possibly be made to this procedure. If the landowner should desire URI to leave a well or wells open, URI will do so after informing the landowner of the water quality of the well(s). In addition, URI may elect to fill the well bore entirely with cement, up to the three (3) feet level.

All surface structures will be removed from the property after mining activity has ceased. Tanks, lines, pumps and structural steel will be disposed of in a manner similar to that for well field equipment. Concrete pads will be decontaminated by acid scrubbing, demolished and disposed of in a licensed solid waste facility. If the surface owner should desire that URI leave any concrete slabs, URI will limit its obligation to decontamination after first notifying the State of Texas and is in receipt of approval for such action.

All fluids held in waste retention ponds will be evacuated and disposed by deep well injection. Any remaining solid waste will either be solubilized and injected as above, or drummed and shipped to a licensed L.S.A. disposal site. Thereafter, the pond liner will be decontaminated, folded and placed in the bottom of the pond. Two (2) feet of impermeable clay will be placed on top of the liner. Pond embankments will then be placed over the clay and graded to a crown in order that water will not be impounded on the pond site. This surface will be seeded with grass to preclude erosion.

Power poles, phone lines and other ancillary equipment will be retained at the discretion of the landowner. Office and maintenance structures will be removed and stored for further use by URI.

CURRENT STATUS

The Benavides Project has been operating successfully since February, 1980. Production during this period has been equal to or above initial projections.

PROJECT SUMMARY

2.11 URANIUM RESOURCES INCORPORATED BENAVIDES PROJECT

Type of operation	commercial
Source material:	
Host rock	sandstone
Permeability, millidarcies	N/A
Porosity, %	N/A
Density, tons/yd^3	N/A
Ground water flow, direction	N/A
Surface elevation, feet above sea level	750
Geologic name	Catahoula
Geologic age	Miocene
Ore characteristics:	
Uranium minerals	N/A
Average grade, % U_3O_8	N/A
Average depth, ft.	200-330
Average thickness, ft.	9
Well field characteristics:	
Total number of wells	N/A
Configuration of well pattern	line drive
Well spacing, ft.	variable
Injection well casing diameter (ID), in.	4.33
Production well casing diameter (ID), in.	4.33
Type of casing	fiberglass
Type of completion	PVC screen

Leaching statistics:

Type of leach solution	sodium bicarbonate
Average concentration, grams/liter	N/A
pH	N/A
Production solution:	
Average uranium content, ppm	60-100
Type of oxidizer	H_2O_2 or oxygen
Average concentration, grams/liter	N/A

Uranium concentration operation:

Type of system	resin ion exchange
Type of equipment	upflow single stage fluid bed columns (4)
Rated capacity, gpm	1600
Eluant	sodium chloride
Precipitation process	peroxide
Final product	yellowcake slurry

Average uranium production, lb/yr	250,000
Type of waste disposal	subsurface injection